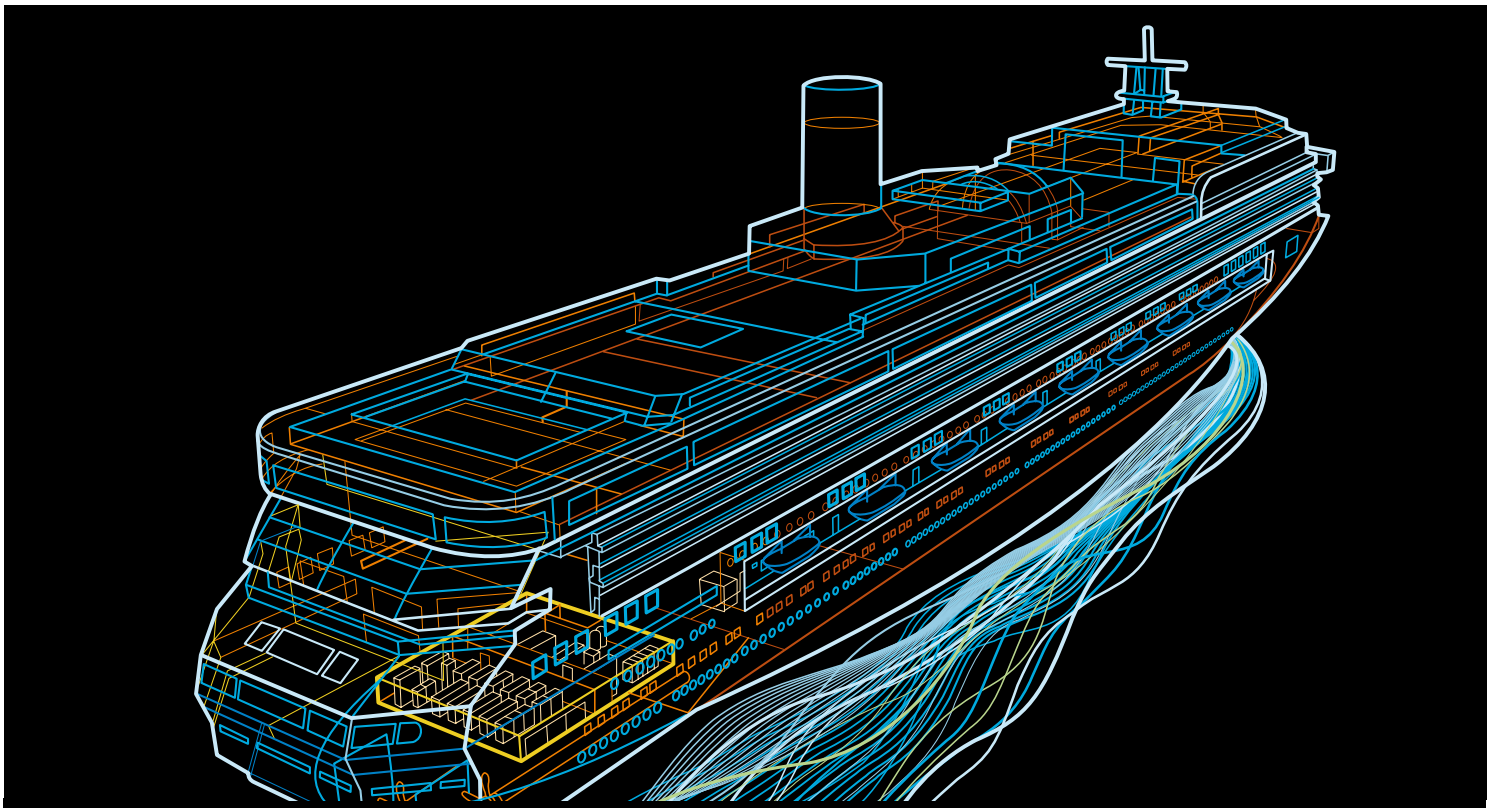


White paper

PR223EF
Zone selectivity with Early Fault Detection and Prevention technology

Power and productivity
for a better world™

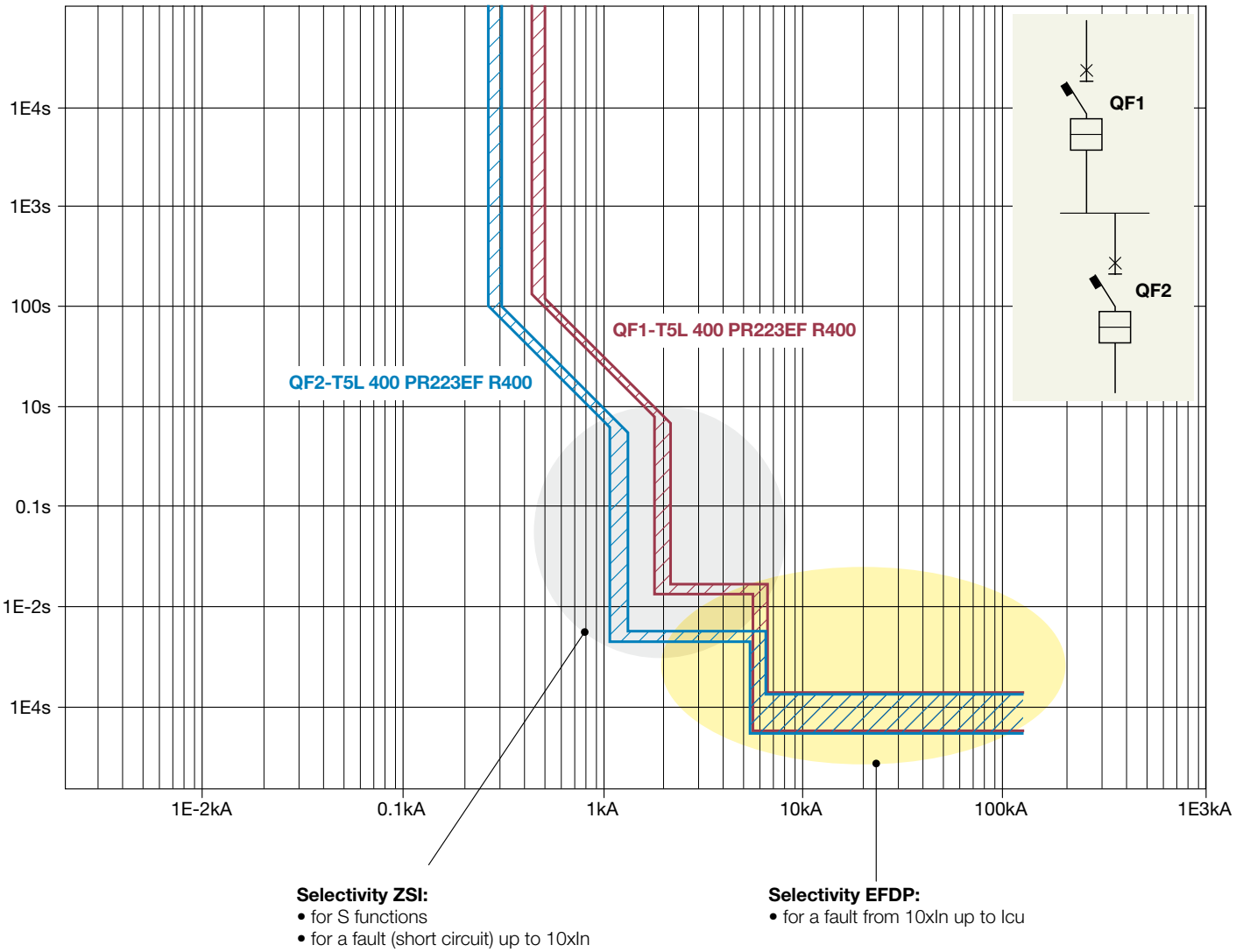
PR223EF: Zone selectivity with Early Fault Detection and Prevention technology

Index

1. Introduction

The purpose of the present document is giving detailed information about the proper use and the correct configuration of the trip unit type PR223EF so as to exploit its potentials at the best and to obtain the maximum advantages in the installations requiring zone selectivity. The aim of this document is not to explain the selectivity theory; to satisfy this need, please refer to the Technical Application Paper “Low voltage selectivity with ABB circuit-breakers” (QT1).

Besides making available Zone Selectivity Interlocking (ZSI) also for molded-case circuit-breakers, the trip unit PR223EF introduces a new concept of selectivity called Early Fault Detection and Prevention (EFDP). If logical selectivity is operating in the range 1…10xIn, EFDP selectivity is usually active approximately in the range from 10xIn and the Icu of the circuit-breaker, thus increasing the normal limit of energy selectivity.



Zone selectivity (ZSI): logical selectivity is based on a wired network so as to achieve a more accurate and increased discrimination range

Logical zone selectivity (ZSI) is an evolution of the time-current selectivity and it is based on the communication between electronic trip units. Thanks to the possibility of sending an interlock signal to the circuit-breaker on the supply side, the delay time of the protections is not increased as moving towards the supply source, while keeping the possibility of discriminating the zone affected by the fault. This selectivity technique is applied to S and G protections.

EFDP (Early Fault Detection and Prevention) technology: thanks to a patented algorithm it allows the selectivity limit between two molded-case circuit-breakers to be increased

EFDP selectivity can be considered as an extension of zone selectivity ZSI to those short-circuit current values where energy selectivity was usually active.

The availability of processors with high calculation power and the development of an algorithm capable to detect the fault condition within 100µsec, together with a very fast transmission protocol, makes it possible to obtain very high selectivity values also using molded-case circuit-breakers.

The algorithm for fault detection developed and patented by ABB has a predictive character since, based on short-circuit current parameters during the initial instant of the fault, it is able to forecast the short-circuit current value before it reaches its maximum.

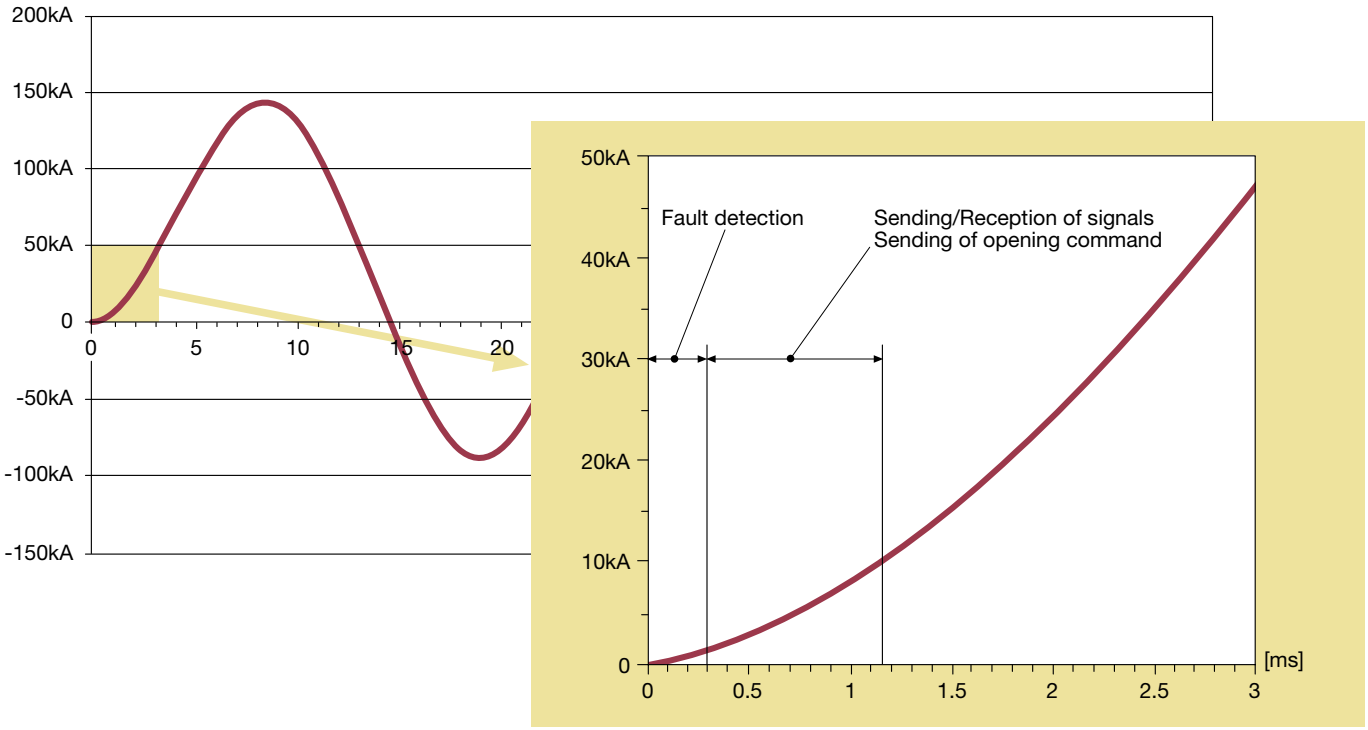
The EFDP system is able to detect the fault, to send a signal to the circuit-breaker on the supply side and to check for a signal coming from the downstream device before starting the contact opening. Thus, the opening of only the circuit-breaker immediately on the supply side of the fault is achieved. In this way we can realize zone selectivity between current-limiting circuit-breakers when fitted with a PR223EF trip unit.

With EFDP zone selectivity, we are able to achieve total selectivity between two circuit-breakers of the same size. On the contrary, when using the traditional method, the upstream circuit-breaker should have been larger in size (thus implying larger overall dimensions) to guarantee selectivity.

EFDP is normally implemented where space is a critical factor, for example in marine applications.

Therefore, Tmax equipped with PR223EF represents a solution to achieve:

- total selectivity between circuit-breakers of the same size
- reduction in the size of the upstream circuit-breakers ensuring selectivity
- total selectivity for rated voltages up to 690V
- circuit-breaker selection only based on rated current.



2. PR223EF: new generation electronic protection unit integrated with zone selectivity

The trip unit PR223EF is available for T4-T5-T6 circuit-breakers of breaking capacity version L.

The table below shows the main characteristics of the protection functions and settings.

2.1 Protection and function

Protection functions		
L	Not excludable. Active in Vaux and in self-supply	I1=0.18...1xIn
S	Excludable. Active in Vaux and in self-supply	I2=0.6...10xIn
EF	Active in Vaux*	
I	Excludable. Active in self-supply*	I3=1.5...12xIn
G	Excludable. Active in Vaux and in self-supply	I4=0.2...1xIn
Logical Interlock	Connection of several PR223EF, by means of shielded twisted pair cable	
Zone selectivity interface with Emax	S51/P1 programmable contact	
Application range	Molded-case breakers from 160 A to 1000 A sizes	
Power supply	24 Vdc (aux) – 0.18 x In (self-supply on one phase)	
Operating frequency	45-66 Hz	
Operating temperature	-25°C...+80°C	
Relative humidity	5%...98%	
Electromagnetic compatibility (LF and HF)	IEC 60947-2 Annex F and N	

* EFDP zone selectivity function can only be obtained when auxiliary voltage is available. Should the auxiliary voltage fail, the EF protection will switch to I protection if it is not excluded (OFF).

2.2 Configuration method

PR223EF is not provided with dip switches for the manual configuration of the parameters. The user has to take one of the following methods, and accordingly, the accessories:

- PR010/T test and configuration unit
- SD-TestBus supervision software through Modbus communication
- BT030

For further information about the protection unit and the configuration procedure please refer to **1SDH000538R0002 (User manual of protection unit PR223EF)**.

2.3 Measurement function

In addition to the protection functions mentioned and described in the previous page, PR223EF trip unit offers the possibility of measuring the main electrical parameters of the network.

Current measurements

The PR223EF trip unit is capable of providing a measure of the currents in the three phases, the neutral and the earth current. The minimum displayable current is 10% In.

Range	0.4…2xIn
Measurement accuracy	+/-3% +/-1digit

Voltage measurements

For this measurement the Vaux and VM210 module must be present. The measurements given refer to the voltage of the three-phases and to the line to line voltage with distributed neutral.

Range	100…1000V
Measurement accuracy	+/-1% +/-1digit

Frequency measurements

For this measurement too the Vaux and VM210 module must be present. The value of the rated mains frequency is set by the user by configuring the suitable parameter (50 or 60 Hz).

Range	45…66Hz
Measurement accuracy	+/-2% +/-1digit

Module VM210

As already said, to carry out some measurements the module VM210 must be used. The following table shows its main characteristics:

VM210 – Service conditions	Values
Voltage supply	24 V DC ± 20%
Ripple	± 5%
Service temperature T	-25° C…+70° C
Relative humidity	5%…98%
Certifications	
Product Stds.	IEC 60068
EMC Stds.	IEC 61000

2.4 Accessories for measurement display

The measurements can be displayed as follows:

Front display unit FDU

The front display unit FDU, which can operate also with self-supply (I> 0.35xIn), is a display unit of the setting currents, alarms and parameters mounted on the front part of the circuit-breakers.

HMI030 display unit

The HMI030 interface is a display unit installed on the front of the switchboard. It consists of a graphic display and navigation push buttons. The HMI unit is connected to the trip unit PR223EF through the system bus. This accessory needs Vaux, and it is an alternative to a supervision system.

PR010/T test and configuration unit

The PR010/T unit is a device which, besides carrying out test and programming functions, allows the reading of the electrical parameters detected by the trip unit. All these functions can be carried out ON BOARD through a connection to the multi-pin connector on the front of the trip unit.

BT030 connection unit

In addition to the possibility of changing the settings and sending commands, this accessory, which can be connected to the trip unit PR223EF through front connector (or via Bluetooth), allows the measurements taken by the trip unit to be displayed on a PC.

Remote supervision system

The values measured by the trip unit PR223EF can be transmitted to communication systems through Modbus RTU protocol (for further references see the Technical Application Paper QT9 “Bus communication with ABB circuit-breakers”).

2.5 Trip history

The PR223EF device stores in the memory the data of the last trip it has detected. The information stored in memory is:

- currents (L1, L2, L3, N) which have resulted in opening
- CB/Relay status
- alarms
- trip
- type of protection tripped
- parameters for the protection tripped

2.6 Supply

Auxiliary voltage.

Characteristics	PR223EF
Power supply voltage	24 Vdc ± 20%
Maximum ripple	5%
Inrush Current @ 24 V	~4 A for 0.5 ms
Start-up Current @ 24 V	~0.5 A for 50 ms
Rated Current @ 24 V	~80 mA
Rated Power @ 24 V	~2 W

3. Application Guide

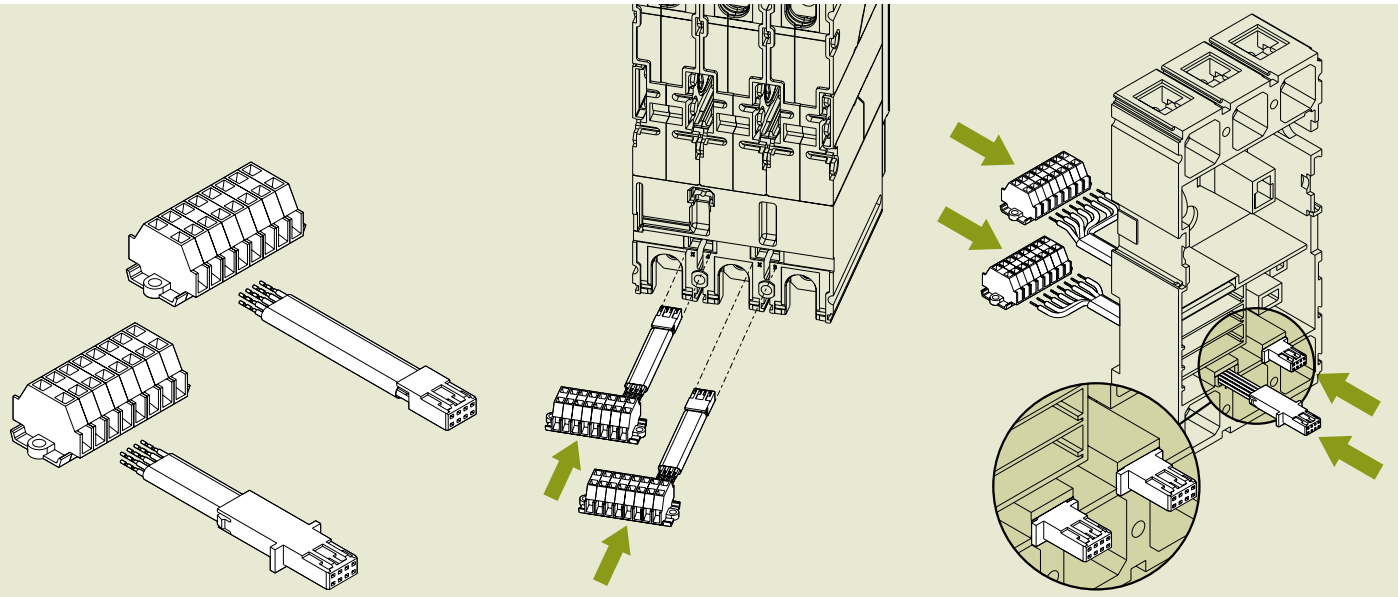
Tmax CBs equipped with PR223EF are normally used in three common system combinations:

	Upstream	Downstream	Chapter
Combination 1	Tmax with PR223EF (T4,T5,T6)	Tmax with PR223EF (T4,T5,T6)	3.1
Combination 2	Tmax with PR223EF (T4,T5,T6)	CB without PR223EF (T2, T1)	3.2
Combination 3	Emax with PR12X/PR33X	Tmax with PR223EF (T4,T5,T6)	3.3

3.1 PR223EF with PR223EF: Total selectivity also with circuit-breakers of the same size

In this case, it is necessary to have X3 and X4 cables in order to connect the PR223EF trip units together and to provide a 24Vdc auxiliary power supply.

Connection of X3, X4 cables



The coordination table is the following:

From 415V up to 690V			Iu[A]	Upstream	T4			T5			T6	
				Version	L			L			L	
				Trip unit	PR223EF			PR223EF			PR223EF	
					250		320	400		630	800	
Downstream	**Version**	**Trip Unit**		**In[A]**	**160**	**250**	**320**	**320**	**400**	**630**	**630**	**800**
T4	**L**	**PR223EF**	**250**	**160**	T	T	T	T	T	T	T	T
				250		T	T	T	T	T	T	T
			320	**320**			T	T	T	T	T	T
T5	**L**	**PR223EF**	**400**	**320**				T	T	T	T	T
				400					T	T	T	T
			630	**630**						T	T	T
T6	**L**	**PR223EF**	**630**	**630**							T	T
			800	**800**								T

This table is valid when the trip units are supplied by auxiliary power and connected with shielded twisted pair cable.

3.1.1 Type of connection

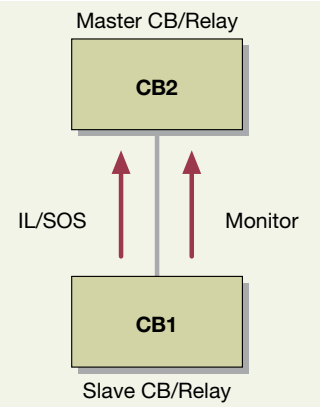
To achieve selectivity between two (or more) circuit-breakers equipped with electronic trip units type PR223EF, it is necessary to realize a connection through a serial connection (IL Bus) thus allowing also molded-case circuit-breakers to obtain zone selectivity.

Within the interlock function IL, the following elements can be identified:

- **CB/Master Relay**: it is the CB/Relay which holds the hierarchically higher level in the IL connection (upstream towards the power supply)
- **CB/Slave Relay**: it is the CB/Relay which is at the hierarchically lower level in the IL connection (downstream towards the load)

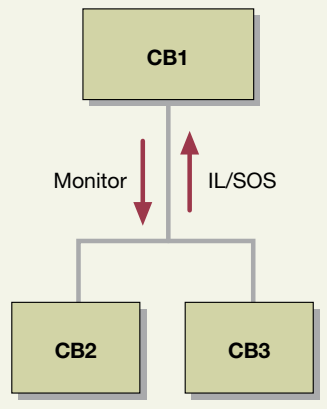
Besides, according to the network typology, two different types of connection are possible:

- **Point-to-Point connection (PP)**:
  one Master and one Slave only (two CB/relays)



As it can be seen in the figure on the left, this is a single-direction type connection; the circuit-breaker CB1 is the Slave sending to the Master (CB2) both alarms and monitoring messages.

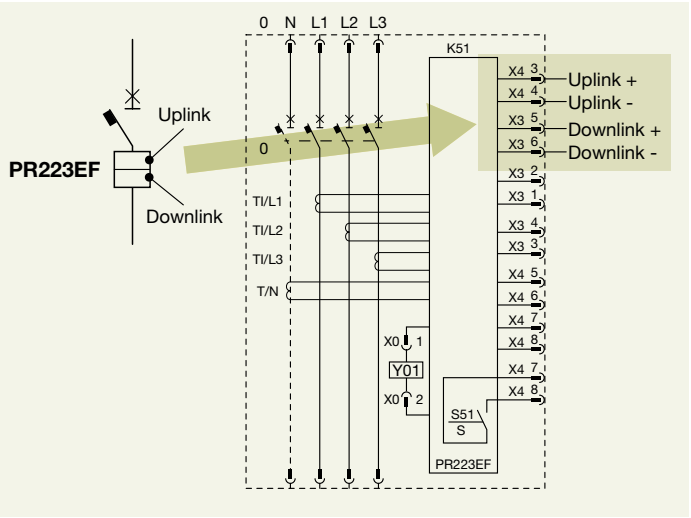
- **Multi-Point connection (MP)**: one Master only but several Slaves (three or more CB/relays, up to 16)



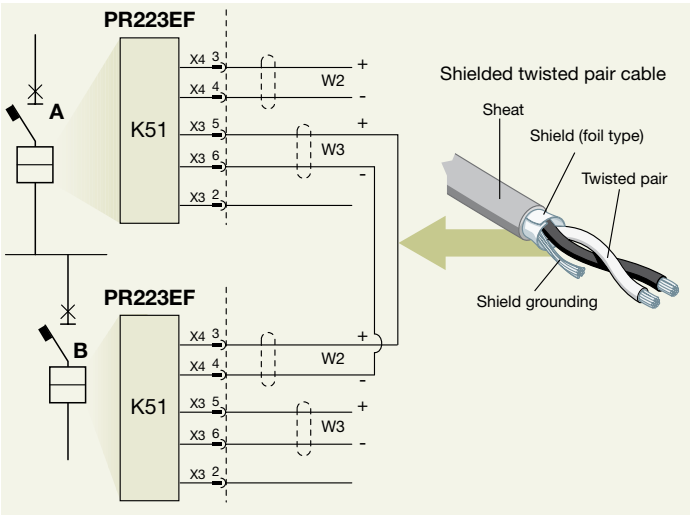
As it can be seen in the figure on the left, this is a two-direction type connection; the circuit-breaker CB1 (Master) sends monitoring messages while the Slaves (CB2-CB3) send alarm messages.

Finally, for each trip unit, there is also:

- **Bus Uplink**: it connects the trip unit to the hierarchically higher level (upstream);
- **Bus Downlink**: it connects the trip unit to the lower hierarchical level (downstream).



The figure below shows the wiring to connect two circuit-breakers A and B in series; they are required to guarantee selectivity with PR223EF only as far as the downlink/uplink terminals are concerned (as regards the complete connection see the example on page 9).



Grounding of the cable shielding shall be carried out on the side of W3 terminal.

Then, for each connected downlink/uplink, it is necessary to program, through SD-Testbus2 or PR010/T, the network configuration in which the PR223EF trip units involved in selectivity work (either point to point or multipoint connection).
Each connection port can be programmed independently and in the above mentioned example it is necessary to program the downlink of the circuit-breaker A and the uplink of the circuit-breaker B as point-to-point connection (PP).
WARNING: This type of connection must be configured for all the relays making up the IL chain. The uplink of the device at the top of the chain must be configured as PP while the downlink of the device at the bottom of the chain must be configured as multipoint connection (MP).

Bus termination: if necessary, the line termination shall be carried out with AC terminators (R=100ohm series C=15nF).

For more information please refer to **1SDH000538R0002 (User manual of the protection unit PR223EF)**.

3.1.2 Configuring a network

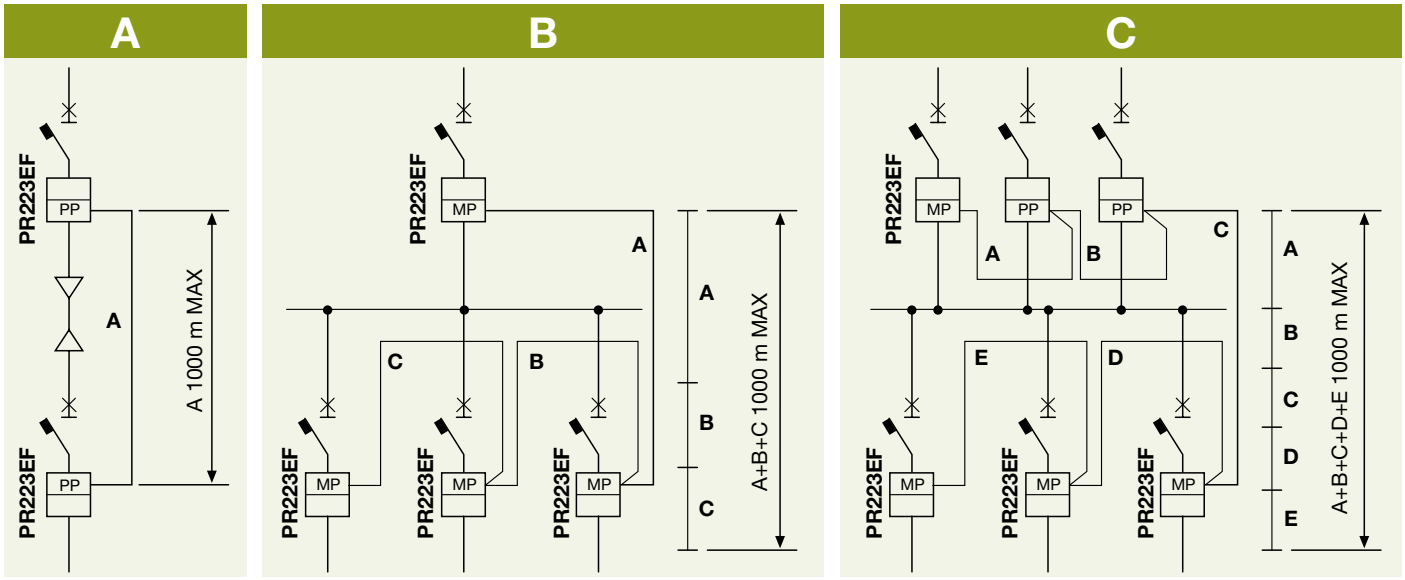
Typical connection configurations are shown in the figure below:

All the possible configurations of a selectivity network are shown above.

Network topology A is the simplest one, with two circuit-breakers connected in cascade. In this case, it is sufficient to configure the uplink port of the downstream device and the downlink port of the upstream device as PP connection.

Network topology B provides one circuit-breaker on the supply side and more circuit-breakers on the load side. In this case, it is sufficient to configure the uplink ports of the downstream devices and the downlink port of the upstream device as MP connection.

Network topology C is the most complex one, characterized as it is by more circuit-breakers on the supply side and more circuit-breakers on the load side.
In this case, all the uplink ports of the downstream devices and **only one port** of the downlink ports of the upstream devices shall be configured as MP, and all the downlink ports of the remaining upstream devices shall be configured as PP.



3.1.3 Connection wiring diagram and “shopping list”

Application Description:

a typical point-to-point connection between two Tmax T5 CBs equipped with the PR223EF trip unit in order to have selectivity between them and communication with a supervision system through Modbus protocol.

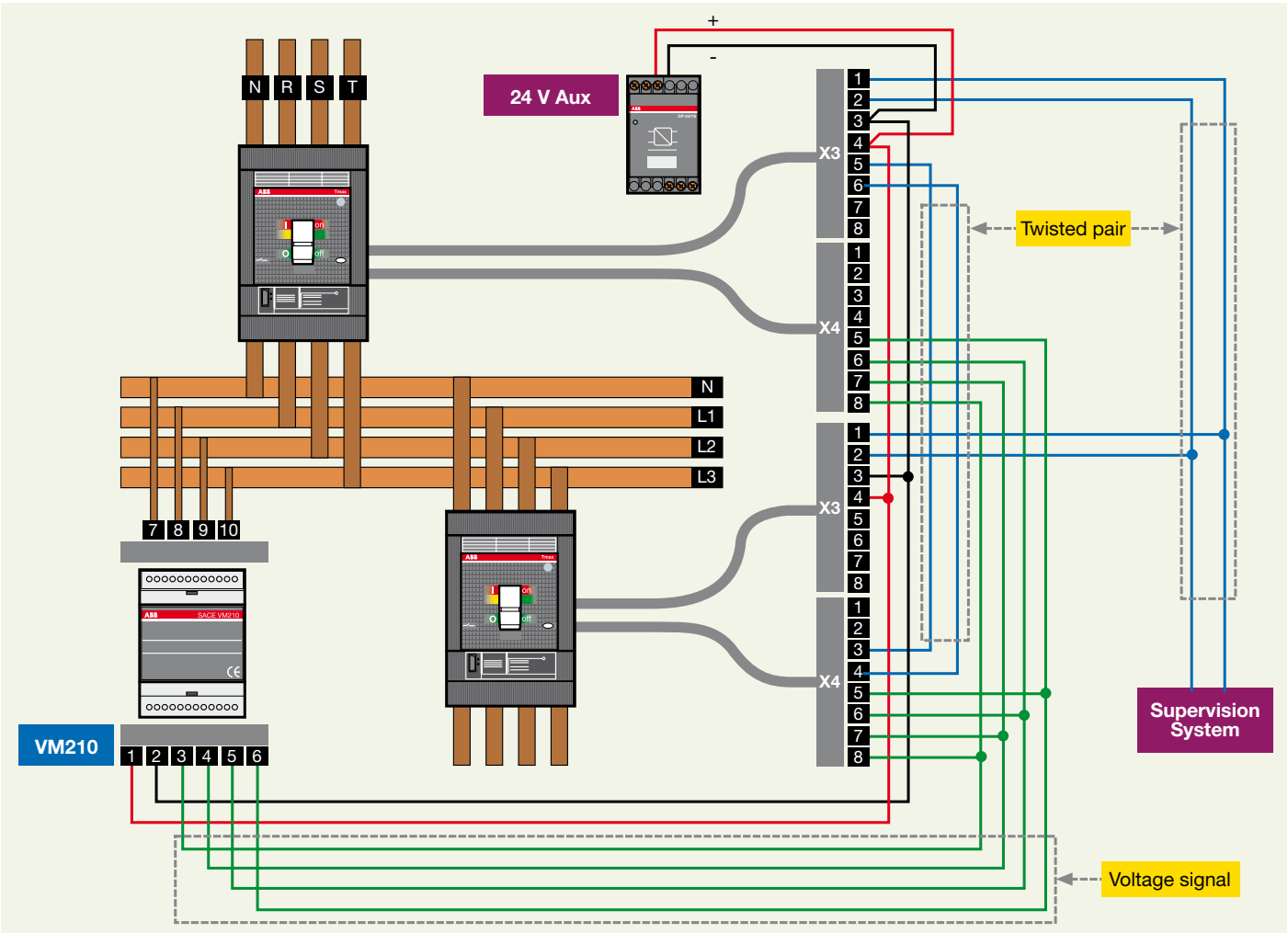
Measurement functions voltage and frequency must be displayed.

Shopping list:

Quantity	ABB Code	Description
1	1SDA059488R1	T5L 630 PR223EF IN=630A 4P F F
1	1SDA059486R1	T5L 400 PR223EF IN=400A 4P F F
1	1SVR 423 418 R0000	CP-24/1.0 90-260 V AC/ 24 VDC power supply
1	1SDA059602R1	VM210 Measurement Module
Up to 1000m		shielded twisted pair cable for RS485 like Belden 3105A

Note: The above listed products and codes are not the only possible choice to make up the network but represent only an example. For further information about the available Tmax with PR223EF, the relevant accessories and ordering codes, please refer to **1SDC210015D0203 - (Tmax Technical Catalogue – Edition 2008)**.

Wiring diagram:



Note

1 if the input of the CP-24/1.0 auxiliary voltage (24VDC) comes directly from the main busbar, and the voltage is out of 90-260VAC range, a LV/LV transformer is needed for the primary supply of the CP-24/1.0 unit.

2 To guarantee zone selectivity, the auxiliary supply of the trip unit can be either the same for all the PR223EF of the plant or it can derive from different sources.

3 The shield must be earthed on the selectivity input side.

In order to achieve selectivity if A is the supply-side circuit-breaker and B the load-side circuit-breaker, the following must be valid:

- $t2_A \geq t2_B + 10ms$
- $t4_A \geq t4_B + 10ms$ (for G selectivity).

3. Application Guide

3.2 PR223EF with PR221 or TM (T1, T2) trip units

In this type of network, PR223EF is not connected via X3, X4 cables to the downstream circuit-breakers to build up a bus communication, but the 24Vdc auxiliary supply is required. The network connection is not different from an ordinary installation with traditional trip units.

PR223EF can distinguish the tripping curves of the downstream T1, T2 circuit-breakers equipped with thermomagnetic or PR221 trip units. If the fault has been detected by the downstream circuit-breakers, the PR223EF will not trip.

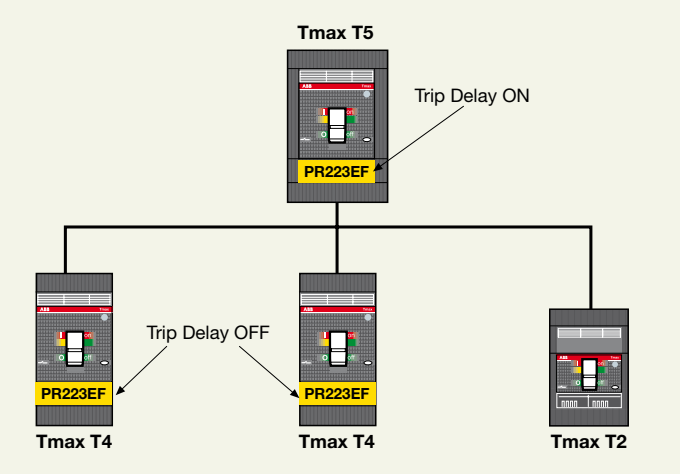
3.2.1 Connection

No connections between the Tmax CB equipped with PR223EF and the CBs with other types of electronic or thermomagnetic trip units are required.

3.2.2 Trip delay

To achieve selectivity with the protection devices downstream closer to the load, which do not have a PR223EF trip unit (e.g. Tmax T1, T2 and miniature circuit-breakers, etc.), it is essential to set the trip delay to the “ON” position.
For the last device in the chain this parameter must be set as shown in the following diagram.
This parameter can be set through Modbus or locally through PR010/T unit.

Trip Delay connection diagram



Coordination table reference:

415V ac			Iu[A]	Upstream	T4			T5			T6	
				Version	L			L			L	
				Trip Unit	PR223EF*			PR223EF*			PR223EF	
					250		320	400		630	800	
Downstream	Version	Trip Unit		In[A]	160	250	320	320	400	630	630	800
T1	B,C,N	TM	160	16-100	T	T	T	T	T	T	T	T
				125		T	T	T	T	T	T	T
				160		T	T	T	T	T	T	T
T2	N,S,H,L	TM, EL	160	10-100	75**	75**	75**	T	T	T	T	T
				125		75**	75**	T	T	T	T	T
				160		75**	75**	T	T	T	T	T

* Trip delayed must be set to “ON” and auxiliary power supply must be present

** Select the lower one of the two values, the indicated one or the breaking capacity of the circuit-breaker on the load side. Consider the system voltage as well.

3.3 PR223EF with PR12X / PR33X: Zone selectivity between ACBs and MCCBs

Thanks to the possibility of programming the contact S51/P of PR223EF, zone selectivity (ZSI) can be achieved between air circuit-breakers and molded-case circuit-breakers. This operation can be performed both using PR010/T or SD Testbus by entering the program mode and choosing S&G Selectivity.

Advantages of the application

When a fault occurs downstream the PR223EF unit, the trip unit will start timing and then will close S51/P1. The PR122 (or PR123, PR332, PR333) will detect the fault current but at the same time it will also receive a blocking signal from the PR223EF. Therefore the PR122 (or PR123, PR332, PR333) will start timing - according to the time delay t2 - for the PR223EF to trip.

When a fault occurs downstream the PR122 (or PR123, PR332, PR333), the PR223EF does NOT detect the fault and will therefore not take any action. The contact S51/P1 will remain in the open position. In this case, the PR12X or PR33X will detect the fault current, but does NOT receive a blocking signal from the PR223EF and will consequently start the internal timing function. A trip action will take place according to the selectivity time (td), than can be considerably shorter than t2 reducing the I2t to be withstood

3.3.1 Connection and configuration

As an example, the following diagram shows a typical connection between PR223EF and Emax PR12X or PR33X trip units in order to achieve zone selectivity (of S function).

In order to achieve selectivity, the following must be valid:

- both trip units must be supplied with 24VDC
- zone selectivity of S protection (or in alternative G if required) must be set to the “ON” (for the upstream circuit-breakers)
- the contact S51/P1 must be programmed according to the protection function you want to coordinate with Emax trip unit (e.g. S or in alternative G protection)
- trip time t2 and td (selectivity time of S) of the Emax on the supply side must be set in the following way:

selectivity time (td)	set so as to realize time-current selectivity with other devices on the load side outside the zone selectivity chain
t2 (function S)	set so as to guarantee that the circuit-breaker which receives the lock signal does not trip, i.e: t2Emax> t2ef+70ms

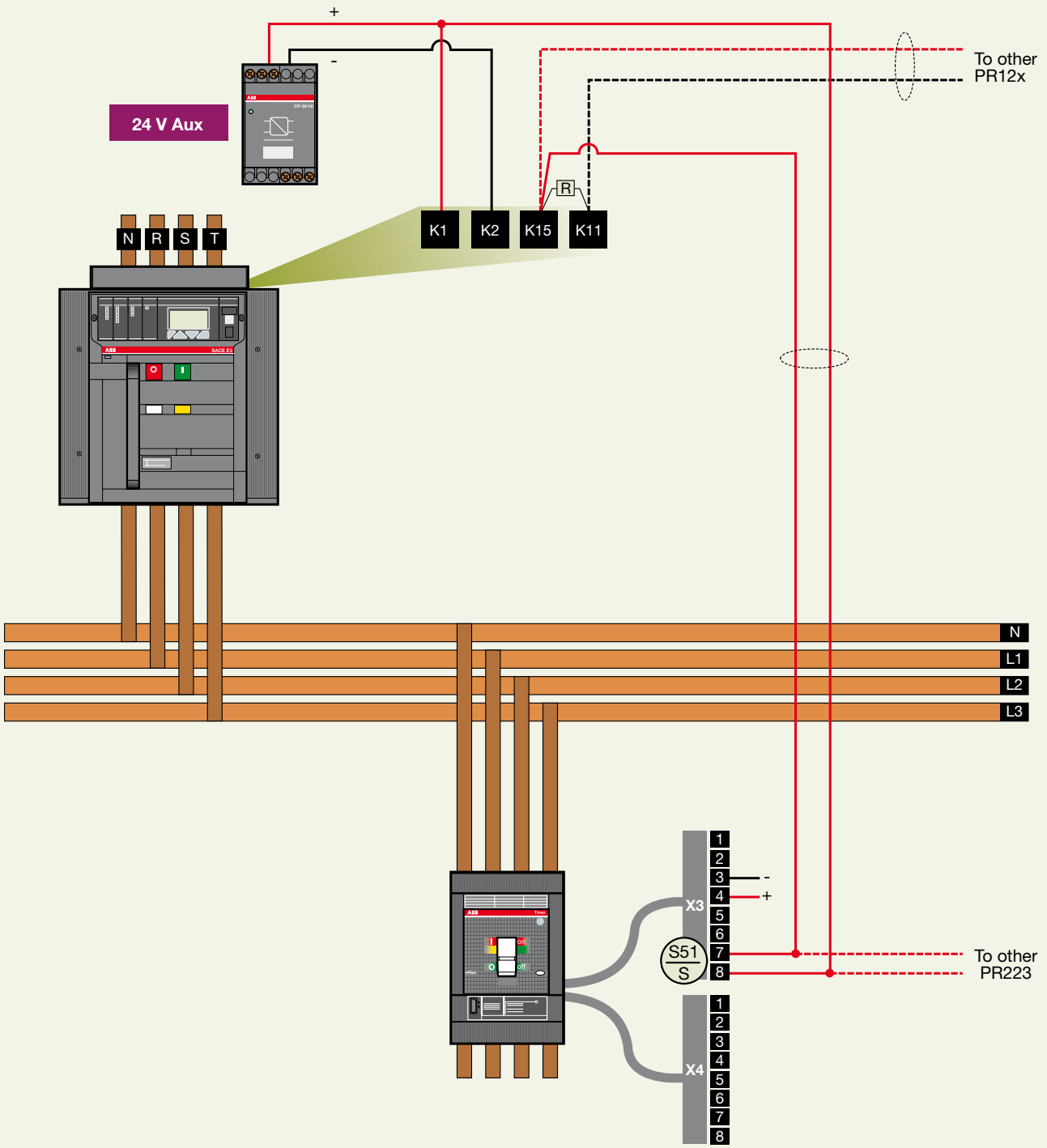
as an alternative to G protection:

selectivity time of G	set so as to achieve time-current selectivity in the case of earth fault, with other devices on the load side outside the zone selectivity chain
t4 (function G)	set so as to guarantee that the circuit-breaker which receives the blocking signal does not trip, i.e: t4Emax> t4ef+70ms

For a proper wiring, the following issues must be taken into account:

- in order to increase immunity to disturbances, a shielded twisted pair cable (e.g. Belden 3105A) is required for the interlocking connections;
- the resistor must be 4.7Kohm 1W and must be connected as close as possible to the Emax terminal block.

3. Application Guide



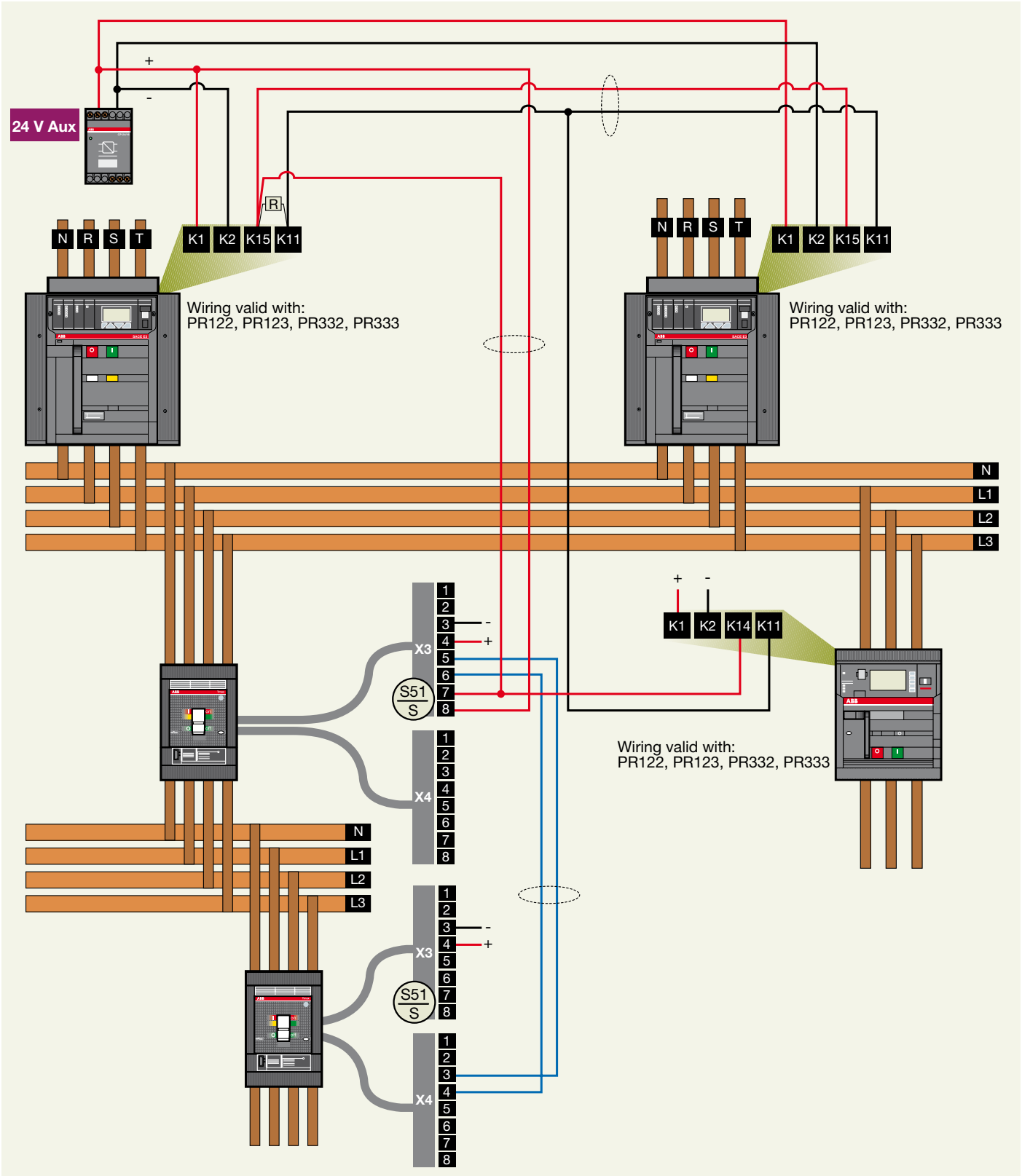
S51/P1: Relay output for programmable signaling
(see PR223EF ModbusTM System Interface doc. 1SDH000566R0002)
Monostable contact, also active when self-powered.

Contact type: **PhotoMos**
Vmax: **48 VDC/ 30 VAC**
Imax: **50 mA DC/ 35 mA AC**

The shield must be earthed on the selectivity input side.
The diagram refers to zone selectivity S; if zone selectivity G is required, it is necessary to connect terminals K15 instead of terminals K13.
To guarantee zone selectivity, the auxiliary supply of the trip unit can be either the same for all the PR223EF of the plant or it can derive from different sources.

Annex

The following example shows the proper connections whenever the complexity and number of circuit-breakers involved in zone selectivity increase



The shield must be earthed on the selectivity input side.
To guarantee zone selectivity, the auxiliary supply of the trip unit can be either the same for all the PR223EF of the plant or it can derive from different sources.

Conclusion

Conclusion

With the EFDP zone selectivity function obtained thanks to the PR223EF electronic protection trip unit we can have a more complete range of discrimination and coordination possibilities. This feature contributes highly to achieve power continuity in a supply network.

EFDP allows achieving selectivity between circuit-breakers of the same size in plants with 690V operating voltage and in all those applications where total selectivity is required in the presence of high short-circuit currents.
Besides, in all those projects where the overall dimensions are a fundamental aspect (e.g. marine, data center systems, etc.) the PR223EF trip units represent the most performing solution for selectivity.

This White Paper presents a general application and typical network installation using PR223EF with EFDP zone selectivity characteristic.

For more detailed information regarding the configuration and installation of the Tmax PR223EF please refer to 1SDC210015D0203 - (Tmax Technical Catalogue – Edition 2008) and 1SDH000538R0002 (User manual of protection unit PR223EF). Reference can be made also to the website http://bol.it.abb.com/.

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